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Estimation of Marine Infantry Rifle Squad Load Weight

*Christopher Zaffram
Maj Darrin Whaley
Launa Jennings
Maj Paul Landry*

21-23 June 2005



Outline



- **Objective and Assumptions**
- **Load Weight Demarcations**
- **Methodology**
- **Data Collected**
- **Results**
- **Tools**
- **Summary**



Study Team

- Ms. Launa Jennings
- Maj Paul Landry
- Maj Scott Miller
- Maj Darrin Whaley
- Mr. Christopher Zaffram



Improved Load Bearing Equipment (ILBE) Capability Development Document

(Section 4.2.5.4 – p.5)



- 4.2.5.4. Parameter. Seventeen (17) ILBEs loaded with the Approach March load (threshold); Existence load (objective) will be able to fit in the spaces designated for personal equipment in the AAV when 17 Marines are aboard the AAV. Rationale: The interior configuration of the AAV has been designed to provide Marines with a storage area for packs in addition to seating that is compatible with load bearing equipment. The Approach March load is set as the threshold based on the Concept of Employment of the AAV. **The AAV KPP is to carry 17 combat loaded marines.**

A combat loaded Marine weight is not defined for a single Marine or group of Marines.



Objectives



- Define the weight of the combat loaded infantry rifle squad by billet and as a group
- Establish appropriate weight limits for the combat load
- Determine a representational squad load out, by billet, for various operational modes
- Develop a tool to estimate load weight for the squad across the Marine Expeditionary Rifle Squad (MERS) mission categories and operational modes



Assumptions



- The mission was successful regardless of amount of gear carried by the Marines
- Recommendations about combat load carriage with respect to the individual Marine is strictly from theater observations, not from physiological/medical perspective
- The manpower data provided by Manpower & Reserve Affairs (M&RA) is representative of base weights of the infantry Marine
- The data collected is representative of the load weight that a Marine would typically carry given the same mission and operational mode



Assumptions (cont'd)



- Environment
 - Dry, Rain
 - Day and Night
 - 75-120 degree Fahrenheit temperature
 - Low Humidity
 - Terrain:
 - Iraq - urban, desert
 - Afghanistan – rural villages, mountain topography, desert
- All missions had foot movement of less than 20 miles



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Marine vs. Army Recommended Load Weight Demarcations



- Marines – Took weight of existing gear and made that the requirement
 - Assault load – 73.2 Pounds
 - Approach load – 96.2 Pounds
 - Existence load – 140.5 Pounds
- Army – Conducted studies of optimal load weight carriage
 - Fighting load – 30% of *average* body weight
 - Approach – 45% of *average* body weight
 - Emergency – 75% of *average* body weight

NOTE: Army moved the average body weight stated in the FM 7-10 and FM 21-18 of 160 pounds to 171 pounds in 2002 March which increased the recommended load five pounds.



LCDR Economos' Study



- Attempted to map Marine Corp gear and convert to weight carriage percentage of body weight
- Recommended another demarcation – the sustainment load
 - Assault load – 30% of average body weight
 - Approach load – 45% of average body weight
 - Sustainment load – recommendation of 75% average body weight
 - Existence load – 90 % of average body weight



Load Weight Carriage Optimal Percentages of Body Weight

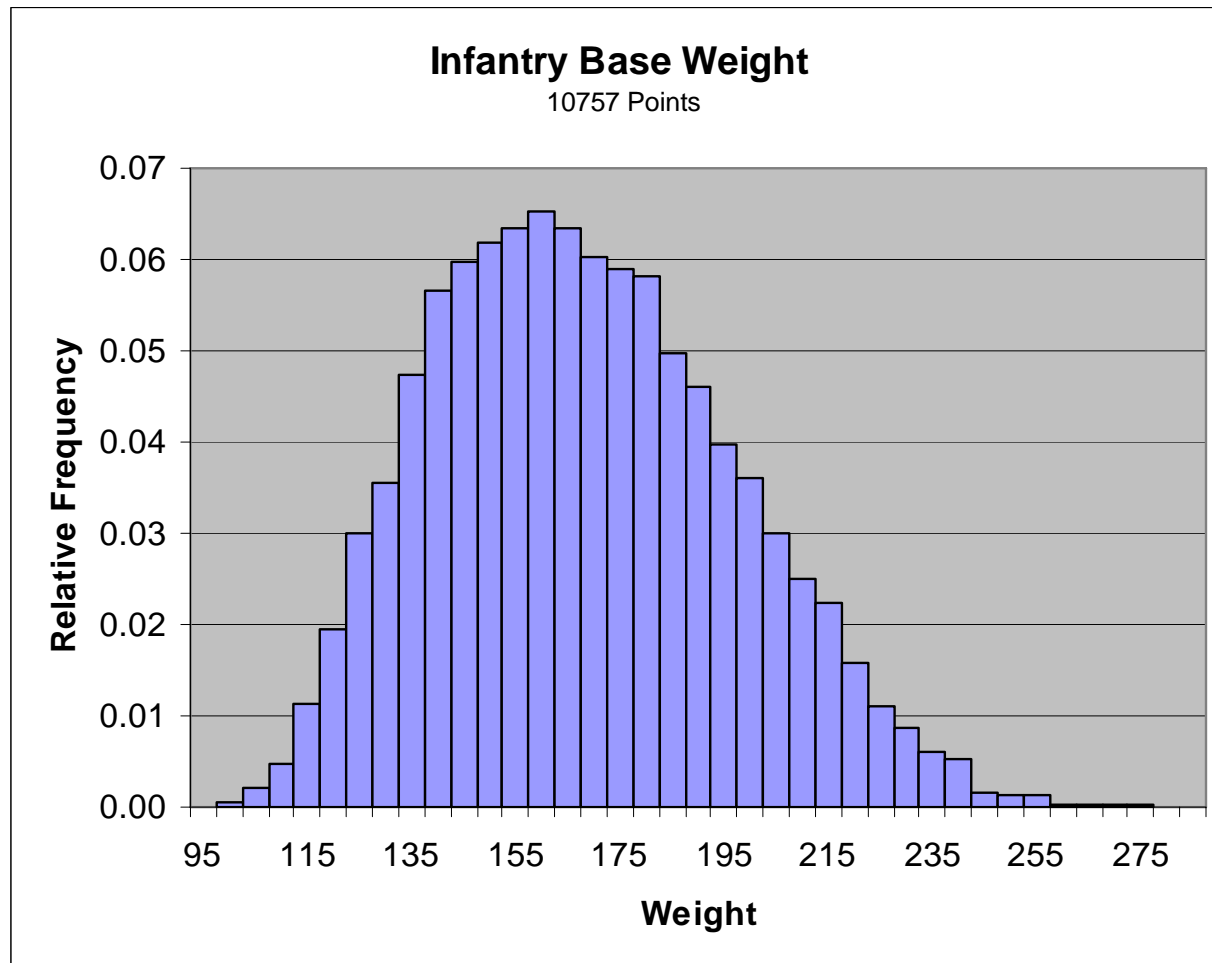


REFERENCE	ASSAULT LOAD	APPROACH MARCH LOAD
MIL-STD-1472F	30%	45%
DOD-HDBK-743A	30%	45%
MIL-HDBK-759C	30%	45%
FM 21-18	30%	45%
FM 7-10	30%	45%

Percentages based on average percent body weight distribution.
(For example, 30% of 171 is 51.3 pounds)




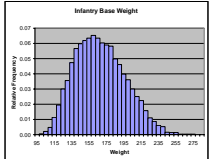
Distribution of Infantry Base Weights from Manpower Database





Initial Percent Body Weight Load Carriage Comparison

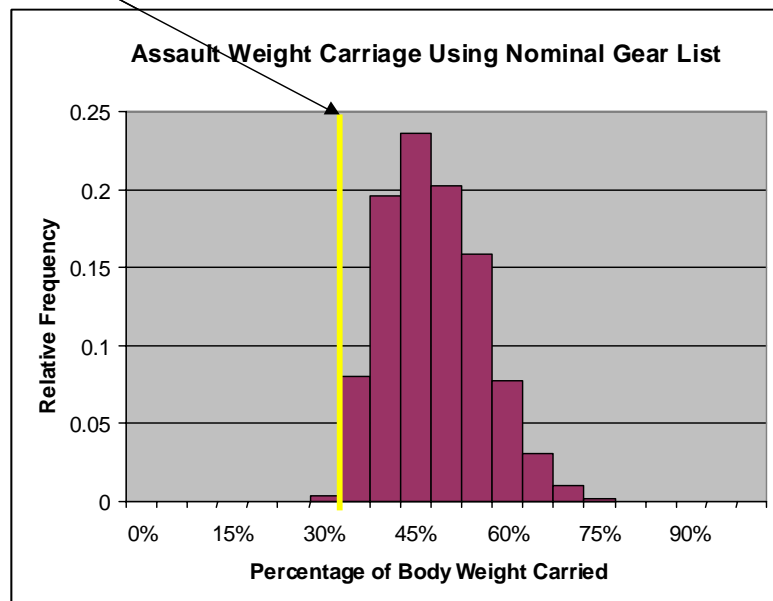


 \div  = % Body Weight Carried

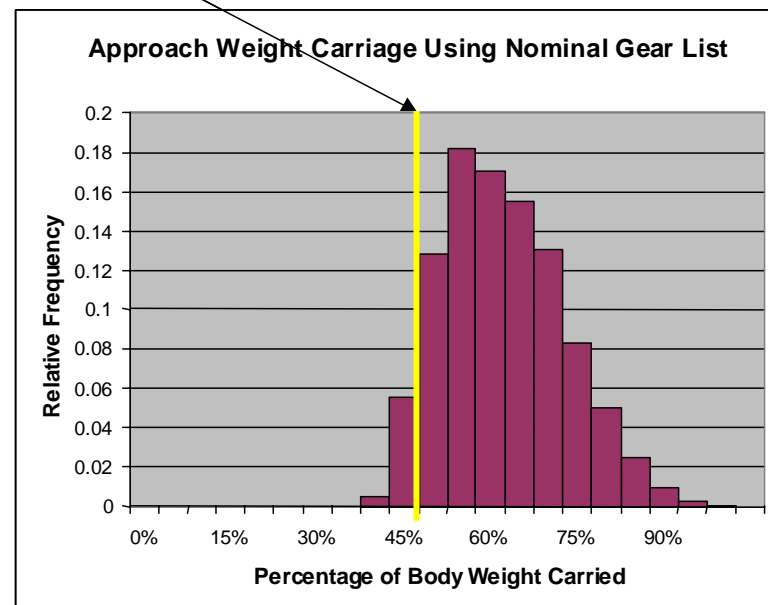
Nominal Gear
(Assault & Approach)

Manpower Base
Weights

Recommended Load Weight 73.2 Pounds gear weight



Recommended Load Weight 96.2 Pounds gear weight

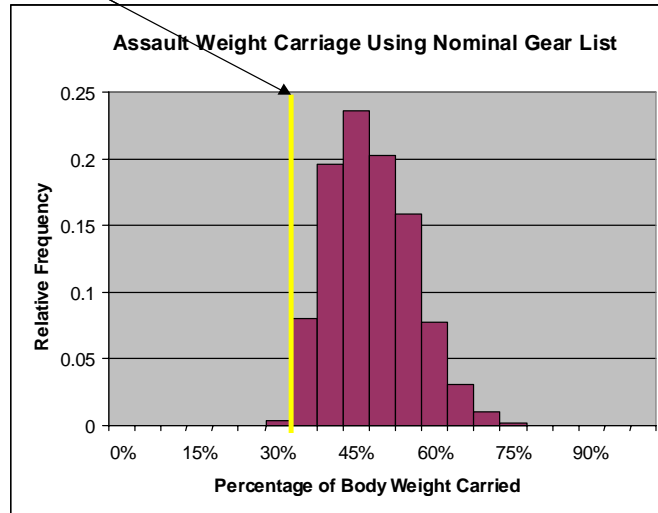




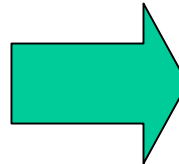
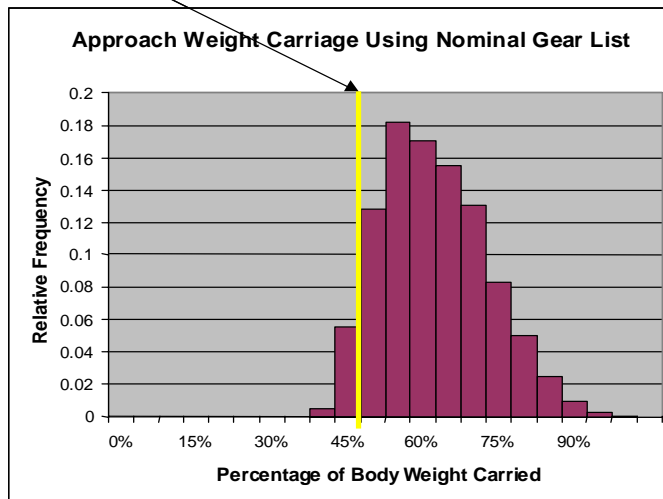
Comparison of Nominal Percent Body Weight Carried to Theater Data



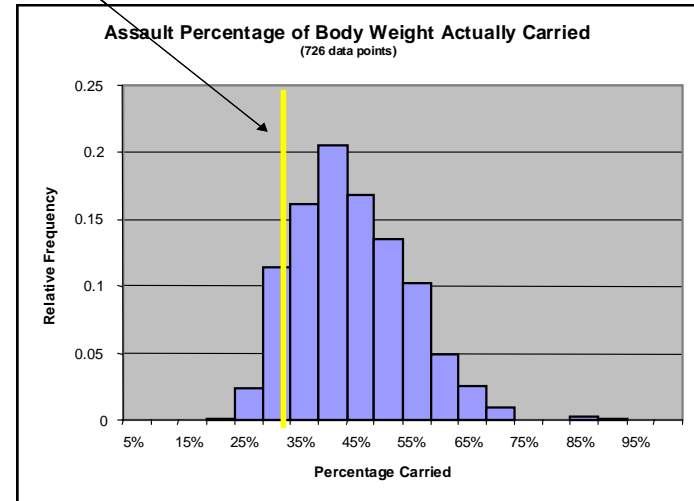
Recommended Load Weight



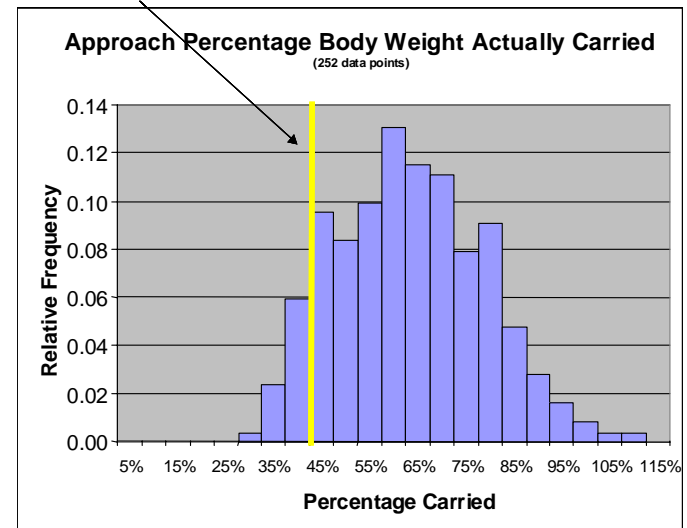
Recommended Load Weight



Recommended Load Carriage



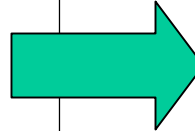
Recommended Load Carriage





Load Weight Demarcations

- Marine Corps
 - Assault Load
 - Approach March Load
 - Sustainment Load
 - Existence Load
- Army
 - Fighting Load
 - Approach March Load
 - Emergency Approach Load



Operational Mode	Anticipated time to first resupply
Assault	< 12
Approach	12-36 hours
Sustainment	36-84 hours
Existence	> 84 hours

Commonality between services was anticipated time to re-supply.



Billet Demarcations

<u>Organizational Group</u>	<u>Billet</u>			
<u>Squad Members</u>	Squad Leader	Fire Team Leader	Automatic Rifleman	Asst Auto Rifleman
	Rifleman			
<u>Infantry Attachments</u>	60 Mort Sect Ldr	Asslt Sect Ldr	Javelin Section Ldr	Med Mach Gun Sect Ldr
	60 Mort Sqd Ldr	Asslt Sect Member	Javelin Team Ldr	Med Mach Gun Sqd Ldr
	60 Mort Sqd Member	Hvy Mach Gun A-Gunner	Javelin Team Member	Mortar FOs
	81 Mort Sect Ldr	Hvy Mach Gun Gunner	Med Mach Gun A-Gunner	Sniper Team Ldr
	81 Mort Sqd Ldr	Hvy Mach Gun Sect Ldr	Med Mach Gun Gunner	Sniper Team Member
	81 Mort Sqd Member	Hvy Mach Gun Sqd Ldr		
<u>Non-infantry Attachment</u>	Arty Scout FO (enlisted)	Engineer Sqd Ldr	EOD Team Member	Radio Operator
	Company Corpsman	Engineer Sqd Member	FAC (enlisted)	Translator
	Corpsman	EOD Team Ldr	Plt Corpsman	UAV Team Member



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- Load Weight Demarcations
- **Methodology**
- **Data Collected**
- **Results**
- **Tools**
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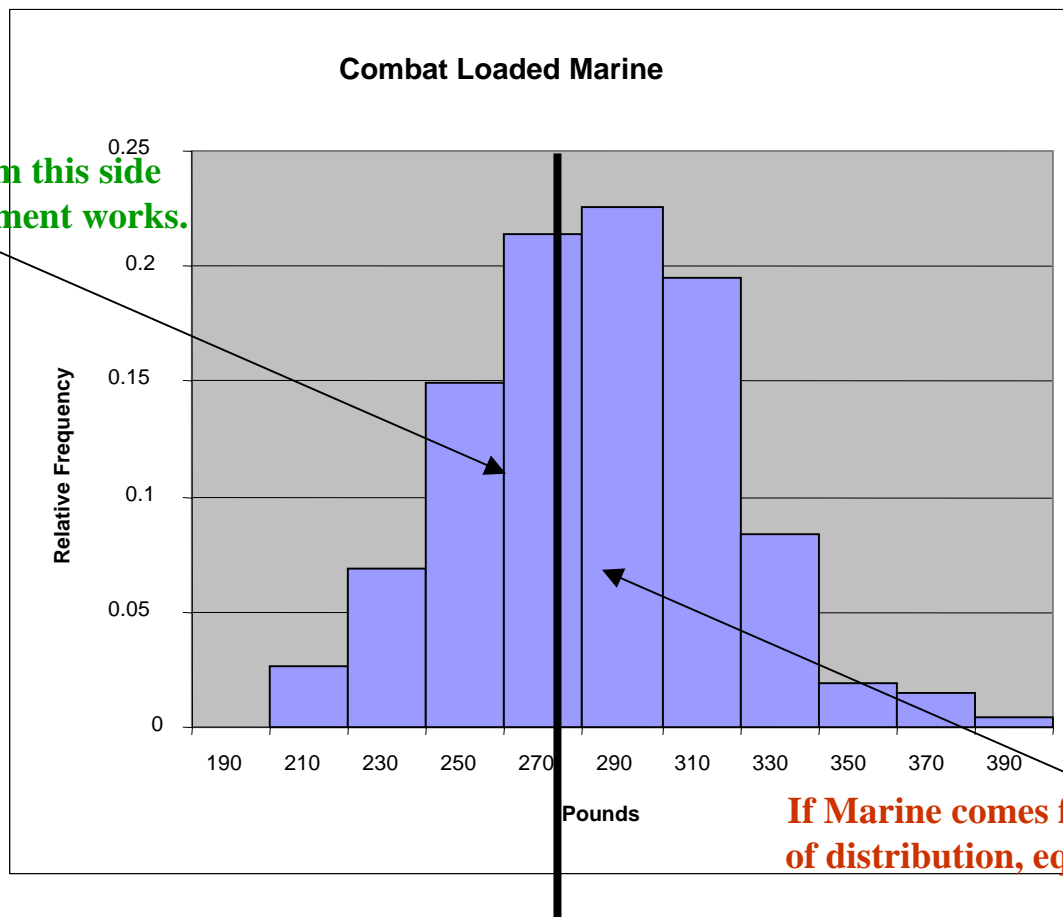
Methodology

- Collect combat load and combat loaded Marine infantry rifle squad theater data across Marine Expeditionary Rifle Squad missions
- Use weight distribution percentiles instead of averages to describe weight estimates



The Rationale Against Building Equipment to the Average

If Marine comes from this side of distribution, equipment works.



If Marine comes from this side of distribution, equipment fails.

Avg = 273.9 Pounds

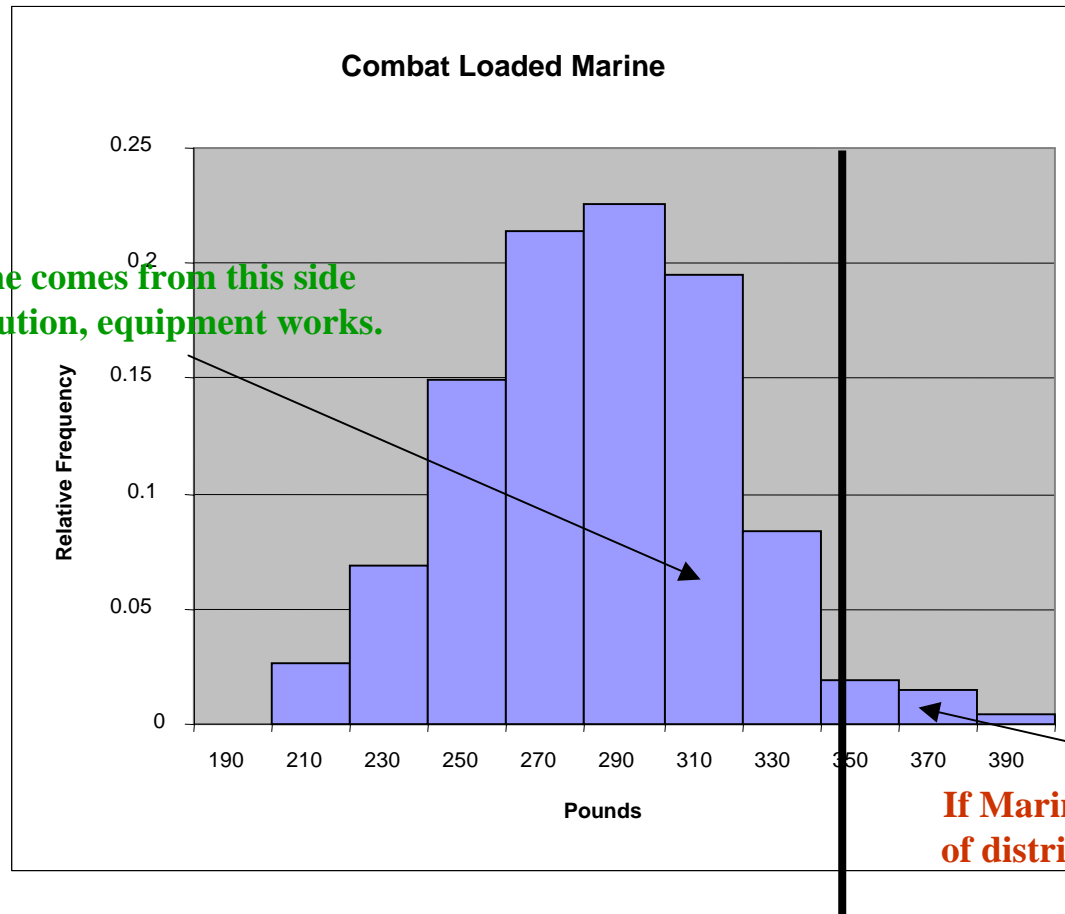
Chances of success equivalent to flipping a coin!



The Rationale for Building Equipment to a Percentile Estimation



If Marine comes from this side of distribution, equipment works.



If Marine comes from this side of distribution, equipment fails.

95th Percentile = 328.6

Only 5% Chance of Failure!



Individual Estimate

The general form of a kernel estimator of $f(x)$ is

$$f(x) = \frac{1}{nh} \sum_{i=1}^n K\left(\frac{x - X_i}{h}\right)$$

where K is a kernel function satisfying

$$\int_{-\infty}^{\infty} K(u) du = 1 .$$

where $u = \left(\frac{x - X_i}{h}\right)$

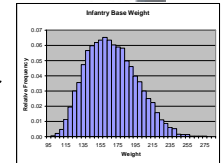
$$\text{Epanechnikov} \quad K(u) = \begin{cases} 0.75(1-u^2) & \text{for } |u| \leq 1 \\ 0 & \text{otherwise} \end{cases}$$

$$\sigma_{se}^2(\%ile) = \left[\frac{p(1-p)}{n(f(\%ile))^2} \right]$$

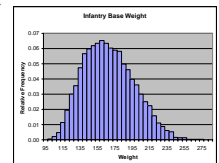
$$h = [8 * c_d^{-1} * (d+4) * (2\sqrt{\pi})^d]^{1/(d+4)} * \sigma * n^{-1/5} \text{ where } d \text{ is the dimension and } c_d = 2.$$



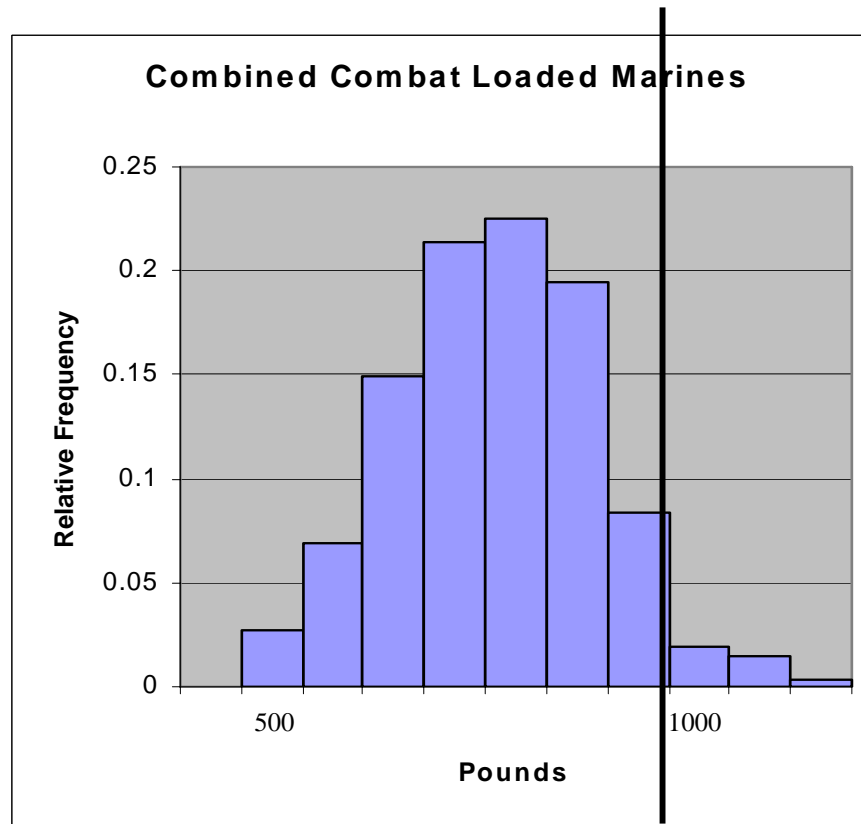
Combining Percentiles for Group Estimation (Fire Team Example)



Automatic Rifleman
Weights

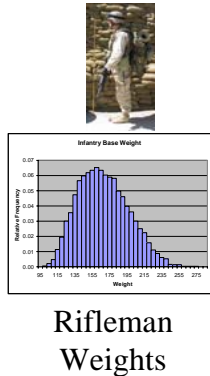
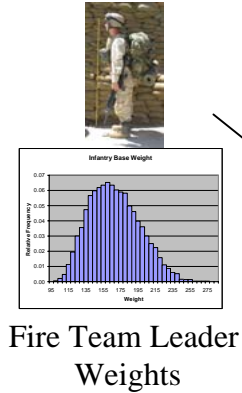


Asst Automatic Rifleman
Weights



Calculate a percentile
per MERS mission
per operational mode

Overall 95th Percentile Estimation, not the
addition of Combat Loaded Marines!





Group Estimate

$$f(\%ile) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(z_\alpha)^2}{2}}$$

$$\sigma_{se}(\%ile) = \sqrt{\left[\frac{p(1-p)}{n(f(\%ile))^2} \right]}$$

$$E(Y) = E(a_1 X_1 + \dots + a_n X_n) = a_1 \mu_1 + \dots + a_n \mu_n$$

$$V(Y) = V(a_1 X_1 + \dots + a_n X_n) = (a_1 \sigma_1)^2 + \dots + (a_n \sigma_n)^2$$



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MERS Mission Categories Data Collected



- Security/Reconnaissance Patrol
- Attack Enemy Dismounted
- Attack Enemy Mounted
- Attack Fortified Position
- Attack Built Up Area
- Combat Patrol
- Attack Dismounted with Mechanized Armor
- Prepare Defensive Positions
- Conduct Local Security Surveillance
- Defeat Enemy Attack
- Consolidation/Reorganization
- Delay and Withdrawal Under Pressure
- Entry Control Point Operations
- Vehicle Check Point
- React to Civil Disturbance
- Detainee Handling
- Cordon and Search
- Provide Convoy Escort
- Tactical Recovery of Personnel & Aircraft*

 = Assault Load only

 = Assault and Approach Loads

* Not a MERS mission category



Data Collected per Data Collector Description per Operational Mode



Assault																				
<i>Billet</i>	Ambush Patrol Motor	Combat Op Mech	Combat Op Motor	Combined Patrol	Cordon and Knock	Cordon and Search	Motorized Patrol	Mvmt to Op	Patrol	Patrol 2-Day	QRF	SEC	SEC Patrol	SEC Patrol Mech	SEC Patrol Motor	SEC QRF	SEC Ambush Patrol	SEC Combat Patrol	Trap	<i>Total</i>
AR	6	5	5	2	0	10	1	4	1	1	8	3	25	1	19	1	3	10	4	109
Asst. AR	0	0	0	0	0	0	0	1	0	0	1	2	0	0	0	2	0	0	0	6
Asst. FTL	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	8
FTL	4	6	5	2	3	8	3	2	1	2	9	8	20	2	20	2	3	11	5	116
Rifleman	9	10	13	4	0	6	3	3	3	5	11	9	17	0	22	3	3	17	8	146
Squad Leader	3	2	2	0	0	7	2	1	2	1	4	3	5	3	9	1	0	8	3	56
<i>Total</i>	22	23	25	8	3	39	9	11	7	9	33	25	67	6	70	9	9	46	20	441

Approach								
<i>Billet</i>	Combat Op Mech	Cordon and Search	Mvmt to Op	Patrol 2-Day	QRF	SEC QRF	Trap	<i>Total</i>
AR	5	10	4	1	8	1	4	33
Asst. AR	0	0	1	0	1	2	0	4
Asst. FTL	0	8	0	0	0	0	0	8
FTL	6	8	2	2	9	2	5	34
Rifleman	10	6	3	5	11	3	8	46
Squad Leader	2	7	1	1	4	1	3	19
<i>Total</i>	23	39	11	9	33	9	20	144

Sustainment			
<i>Billet</i>	Mvmt to Ops	Patrol 2-Day	<i>Total</i>
Automatic Rifleman	4	1	5
Asst. Automatic Rifleman	1	0	1
Fire Team Leader	2	2	4
Grenadier	0	0	0
Rifleman	3	5	8
Squad Leader	1	1	2
<i>Total</i>	11	9	20



Theater Mission Description Mapping to MERS Mission Categories



Mission Description	Security/ Reconnaissance Patrol	Attack Enemy Mounted	Attack Enemy DisMounted	Attack Fortified position	Attack Built-Up area	Combat Patrol	Attack Dismounted with Mech/Armor	Prepare Defensive Positions	Conduct Local Security / Surveillance	Defeat Enemy Attack	Consolidation / Reorganization	Delay & Withdrawal Under Pressure	Entry Control Point (ECP) Ops	Vehicle Check Point (VCP) Ops	React to Civil Disturbance	Detainee/ EPW Handling	Cordon & Search Area	Provide Convoy Escort	
ASSAULT																			TRAP
AMBUSH PATROL MOTORIZED	X					X			X										
SEC PATROL MOTORIZED	X					X			X										
CORDON AND KNOCK	X								X								X		
COMBAT OP MOTORIZED						X		X						X					
COMBAT OP MECHANIZED						X		X						X					
COMBINED PATROL						X													
CURITY PATROL MECHANIZED	X								X										
SEC PATROL	X								X										
SEC	X								X										
SEC/COMBAT PATROL	X					X			X										
SEC/AMBUSH PATROL	X								X										
MOTORIZED PATROL						X													
PATROL						X			X										
2-DAY HIDE																			
PATROL 2-DAY						X													
CORDON AND SEARCH																	X		
TRAP																			X
QRF		X																	
MOVEMENT TO OPS																			
Mission Description	Security/ Reconnaissance Patrol	Attack Enemy Mounted	Attack Enemy DisMounted	Attack Fortified position	Attack Built-Up area	Combat Patrol	Attack Dismounted with Mech/Armor	Prepare defensive positions	Conduct Local Security / Surveillance	Defeat enemy attack	Consolidation / Reorganization	Delay & withdrawal under pressure	Entry Control Point (ECP) Ops	Vehicle Check Point (VCP) Ops	React to Civil Disturbance	Detainee/ EPW Handling	Cordon & Search Area	Provide Convoy Escort	
APPROACH																			TRAP
PATROL																			
AMBUSH PATROL MOTORIZED																			
SEC PATROL MOTORIZED																			
CORDON AND KNOCK																			
COMBAT OP MOTORIZED																			
COMBAT OP MECHANIZED						X		X						X					
COMBINED PATROL																			
CURITY PATROL MECHANIZED																			
SEC PATROL																			
SEC																			
SEC/COMBAT PATROL																			
SEC/AMBUSH PATROL																			
MOTORIZED PATROL																			
2-DAY HIDE						X		X						X					
PATROL 2-DAY						X		X						X					
CORDON AND SEARCH																	X		
TRAP																			X
QRF		X																	
MOVEMENT TO OPS																			



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Theater Example



Rifleman



**Automatic
Rifleman**



**Squad
Leader**



**Assistant
Automatic
Rifleman**

**Squad
Combat
Loaded
Weight
3518.4 Pounds**



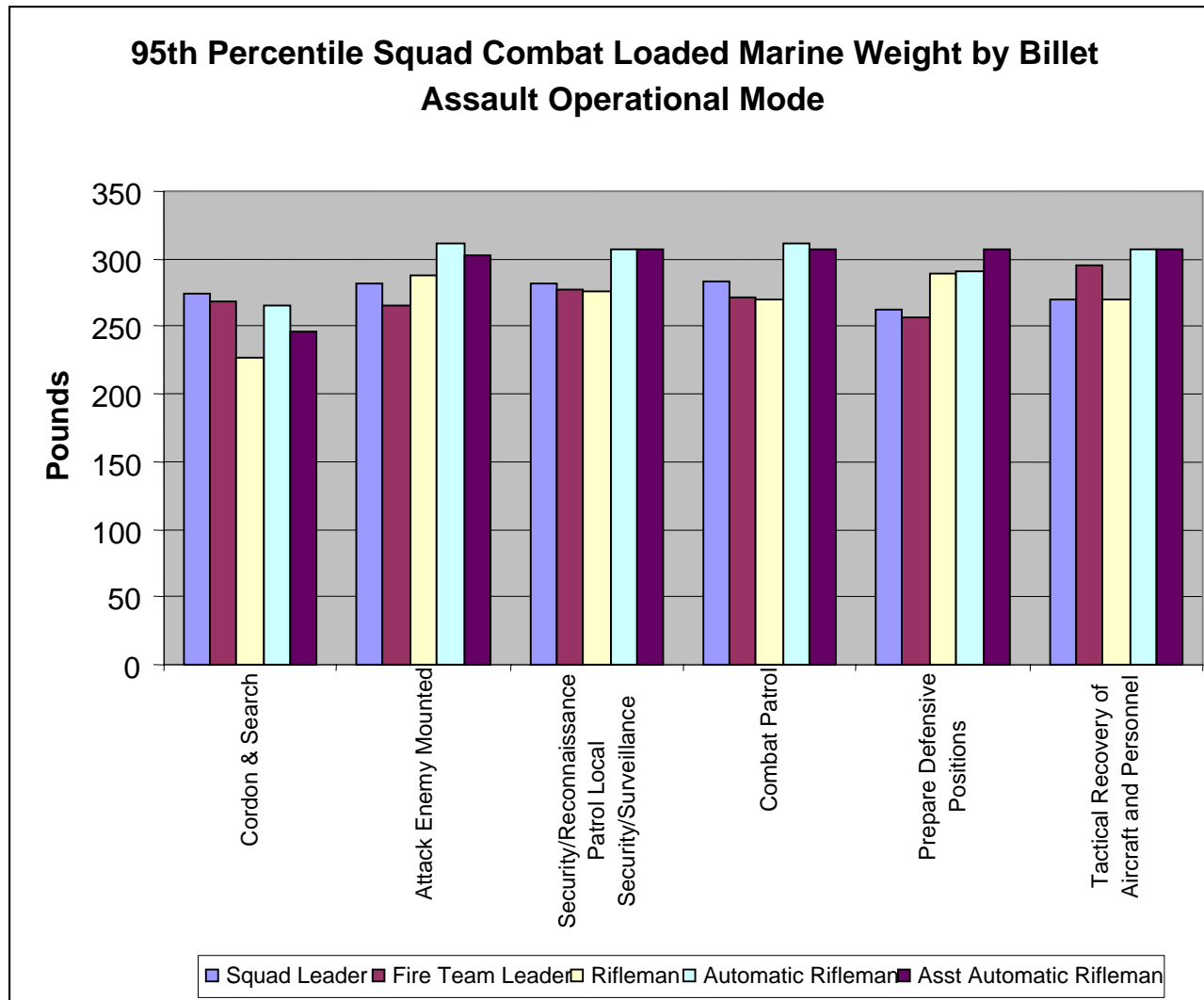
**Fire Team
Leader**





95th Percentile Combat Loaded Marine Weight by Billet for All MERS Missions Collected

(Assault Operational Mode)



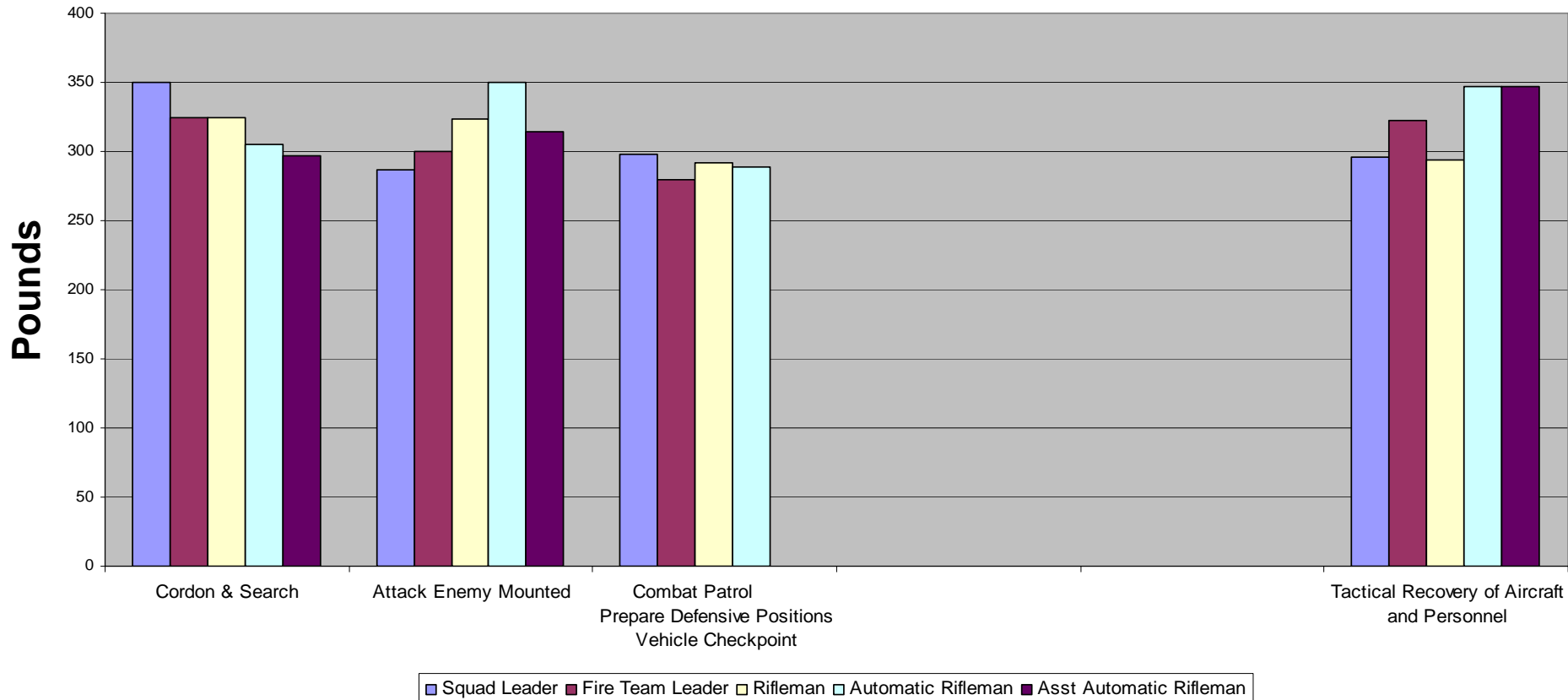


95th Percentile Combat Loaded Marine Weight by Billet for All MERS Missions Collected

(Approach Operational Mode)



95th Percentile Combat Loaded Marine Squad Weight by Billet
Approach Operational Mode



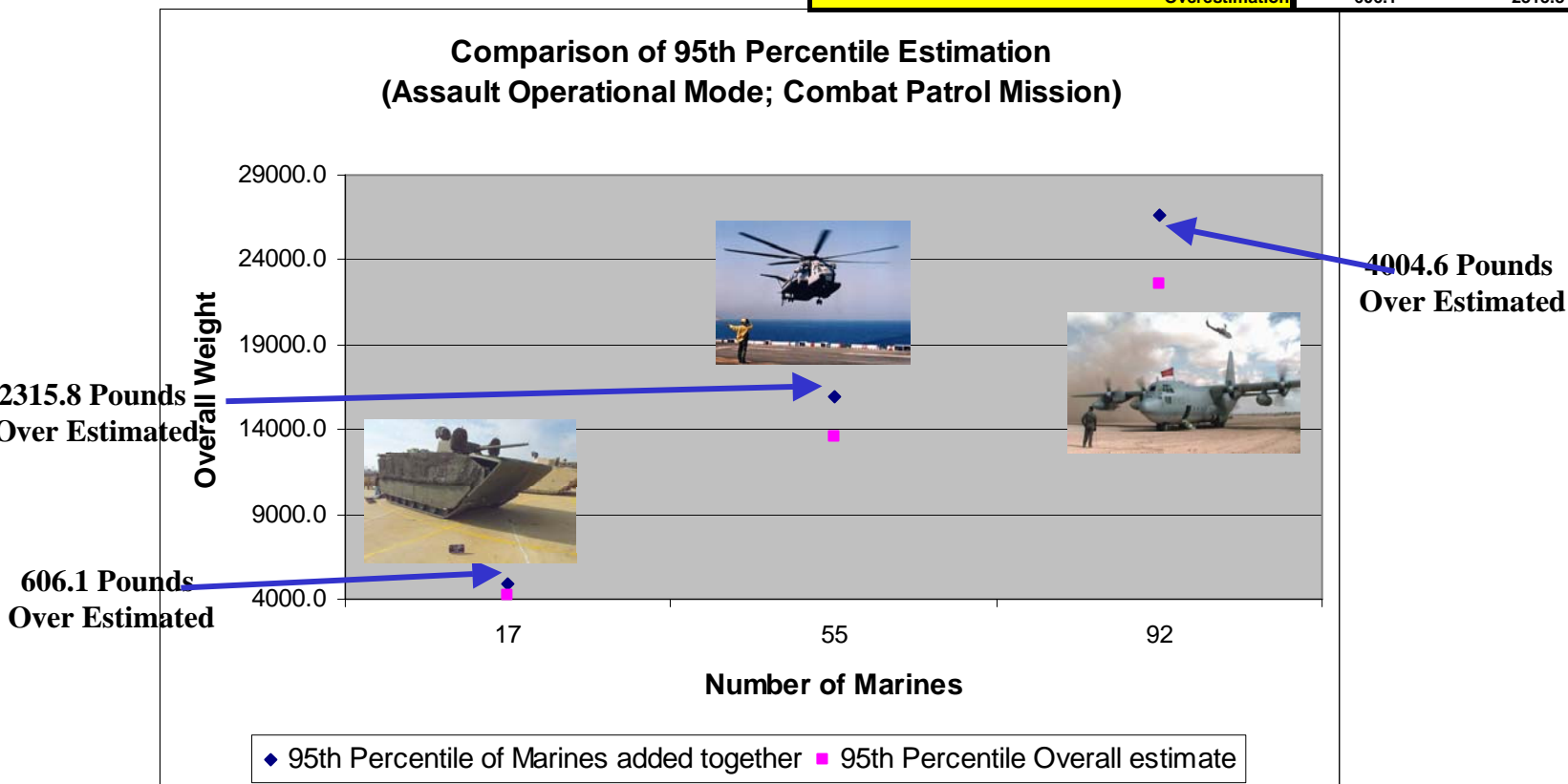


95th Percentile Estimation Comparison

(Assault Operational Mode; Combat Patrol Mission)



Billet	Number of Billet	Number of Billet	Number of Billet
Squad Leader	2	6	12
Fire Team Leader	3	12	20
Rifleman	6	13	20
Automatic Rifleman	3	12	20
Asst. Automatic Rifleman	3	12	20
Total Number of Marines (Combat Patrol Mission)	17	55	92
95th Percentile of Marines added together	4858.1	15890.9	26600.0
95th Percentile Overall estimate	4252.0	13575.1	22595.4
Overestimation	606.1	2315.8	4004.6





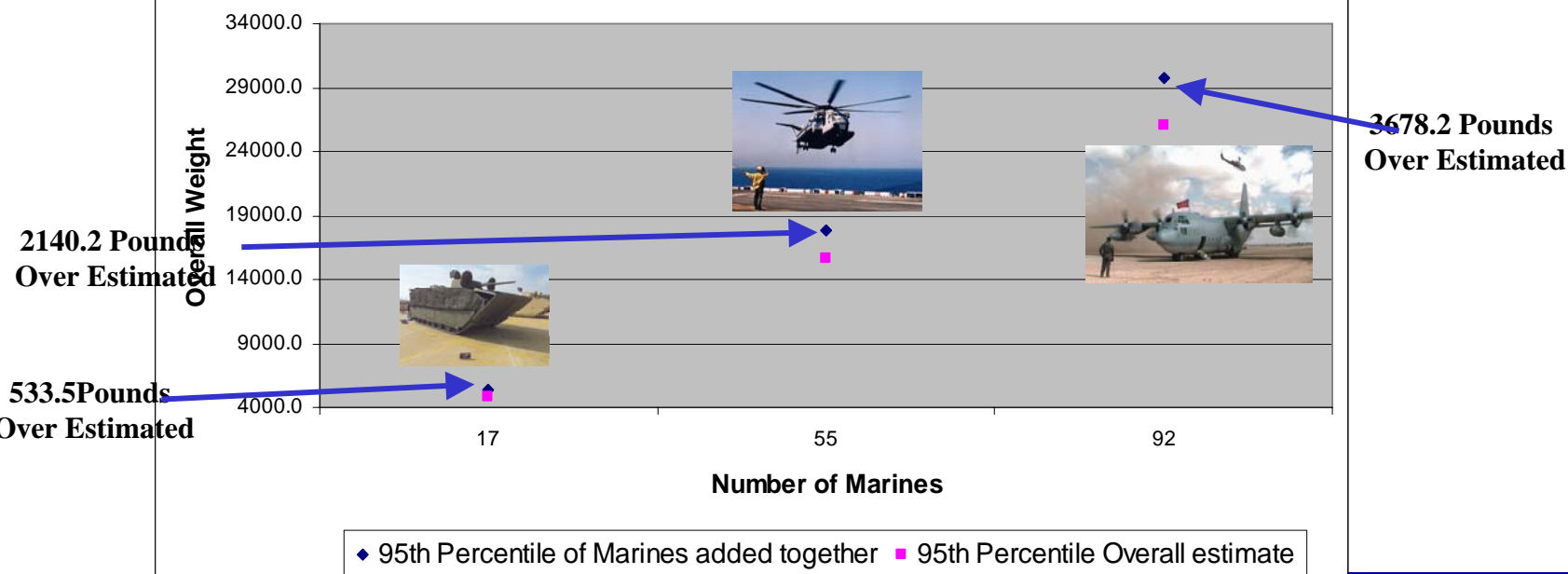
95th Percentile Estimation Comparison

(Approach Operational Mode; TRAP Mission)



Billet	Number of Billet	Number of Billet	Number of Billet
Squad Leader	2	6	12
Fire Team Leader	3	12	20
Rifleman	6	13	20
Automatic Rifleman	3	12	20
Asst. Automatic Rifleman	3	12	20
Total Number of Marines (TRAP Mission)	17	55	92
95th Percentile of Marines added together	5406.0	17795.1	29759.6
95th Percentile Overall estimate	4872.5	15654.9	26081.4
Overestimation	533.5	2140.2	3678.2

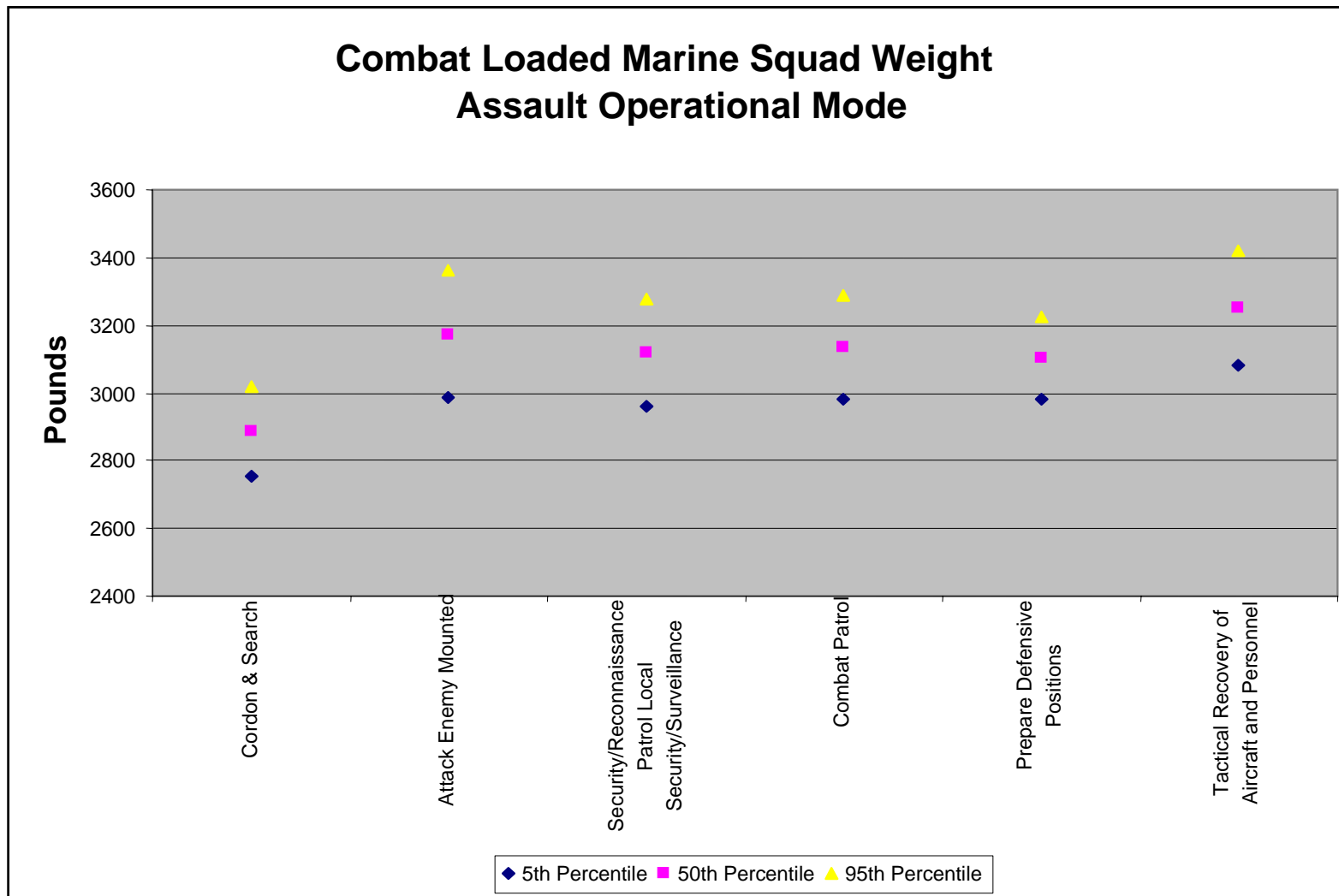
Comparison of 95th Percentile Estimation
(Approach Operational Mode; TRAP Mission)



Simply adding 95th percentile Combat Loaded Marines significantly overestimates requirement...converts into unnecessary cost!



Combat Loaded Marine Squad Group Weight

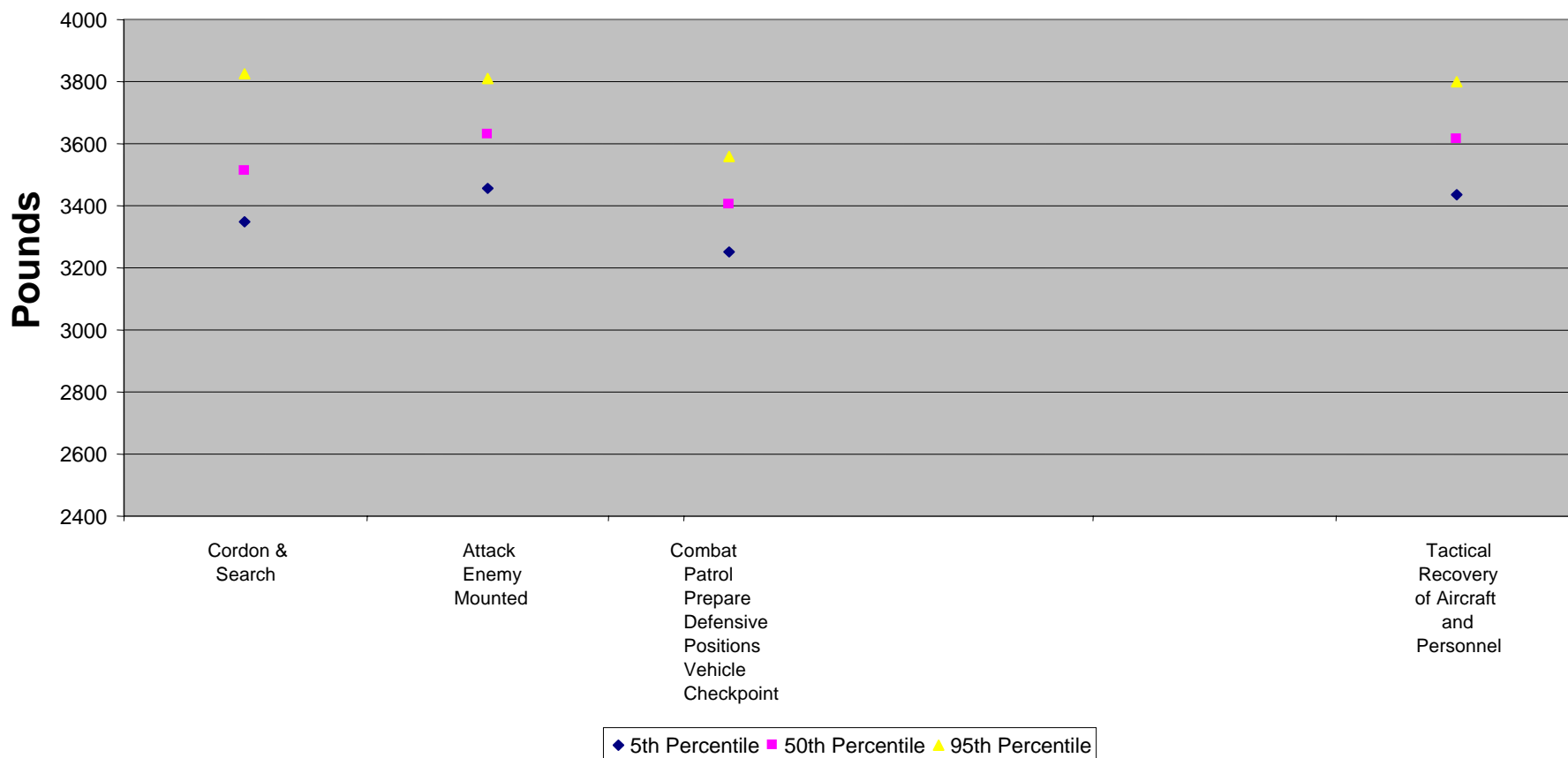




Combat Loaded Marine Squad Group Weight



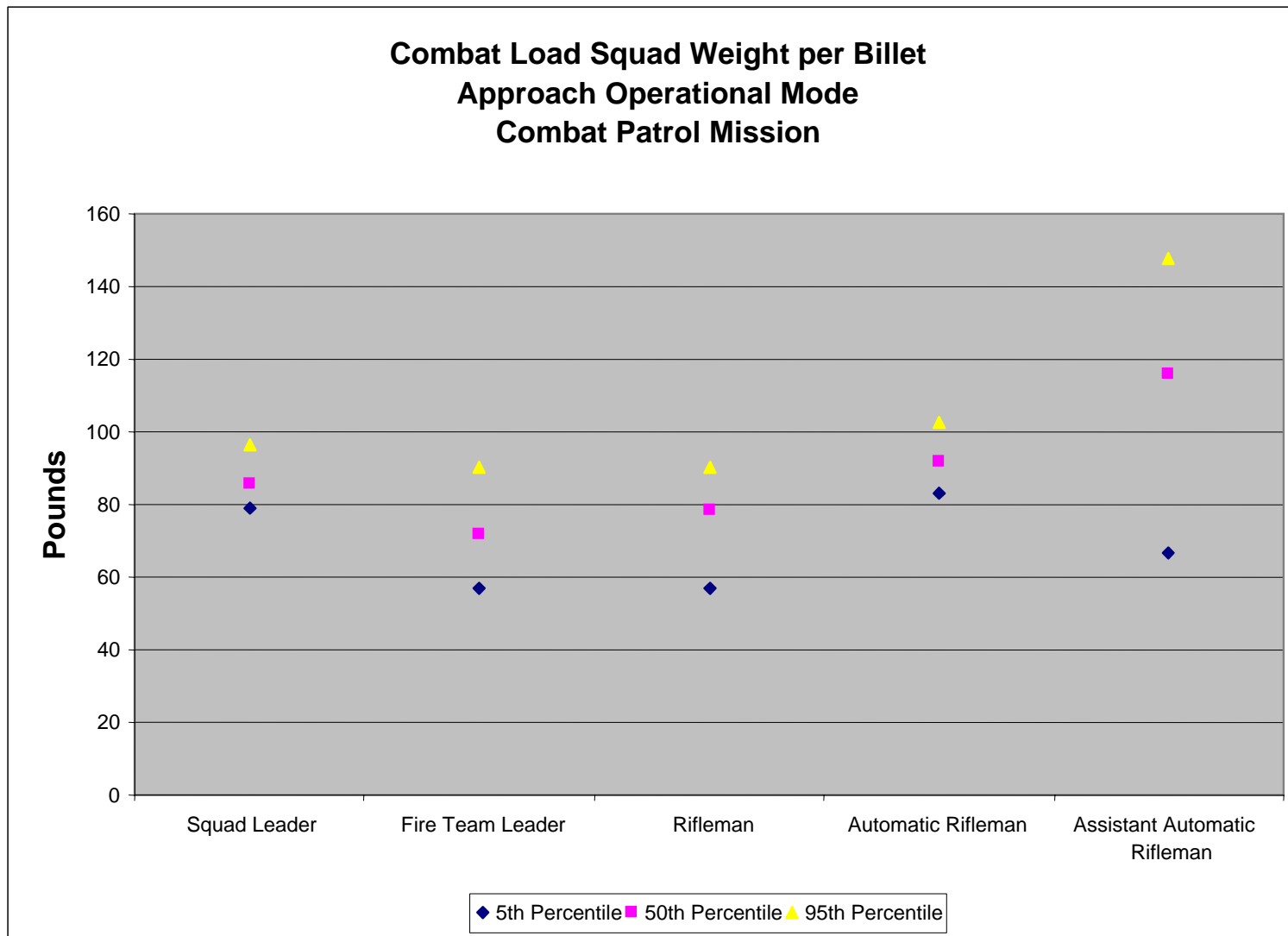
Combat Loaded Marine Squad Weight
Approach Operational Mode





Combat Loads by Billet

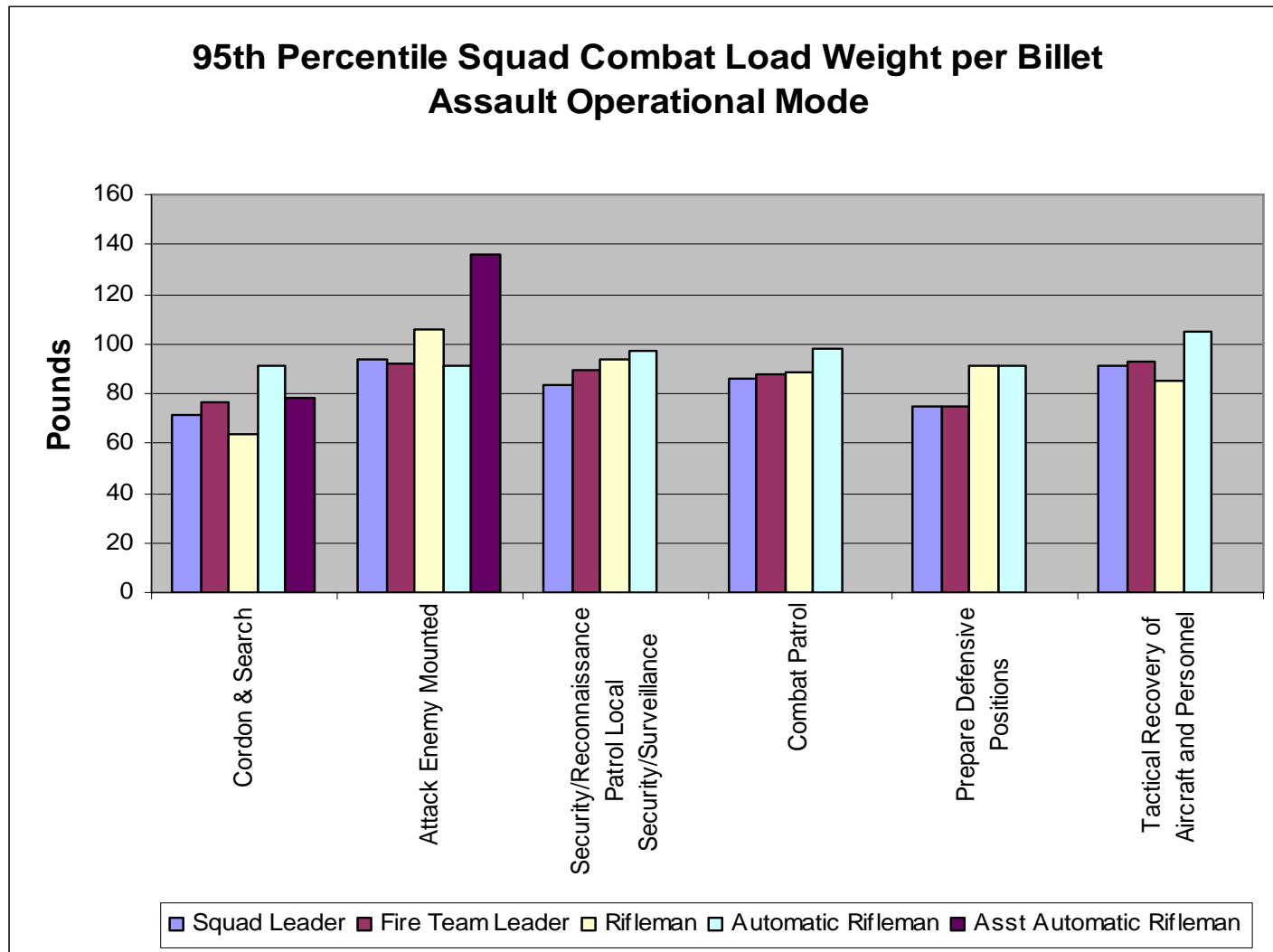
(Assault)





95th Percentile Combat Load by Billet

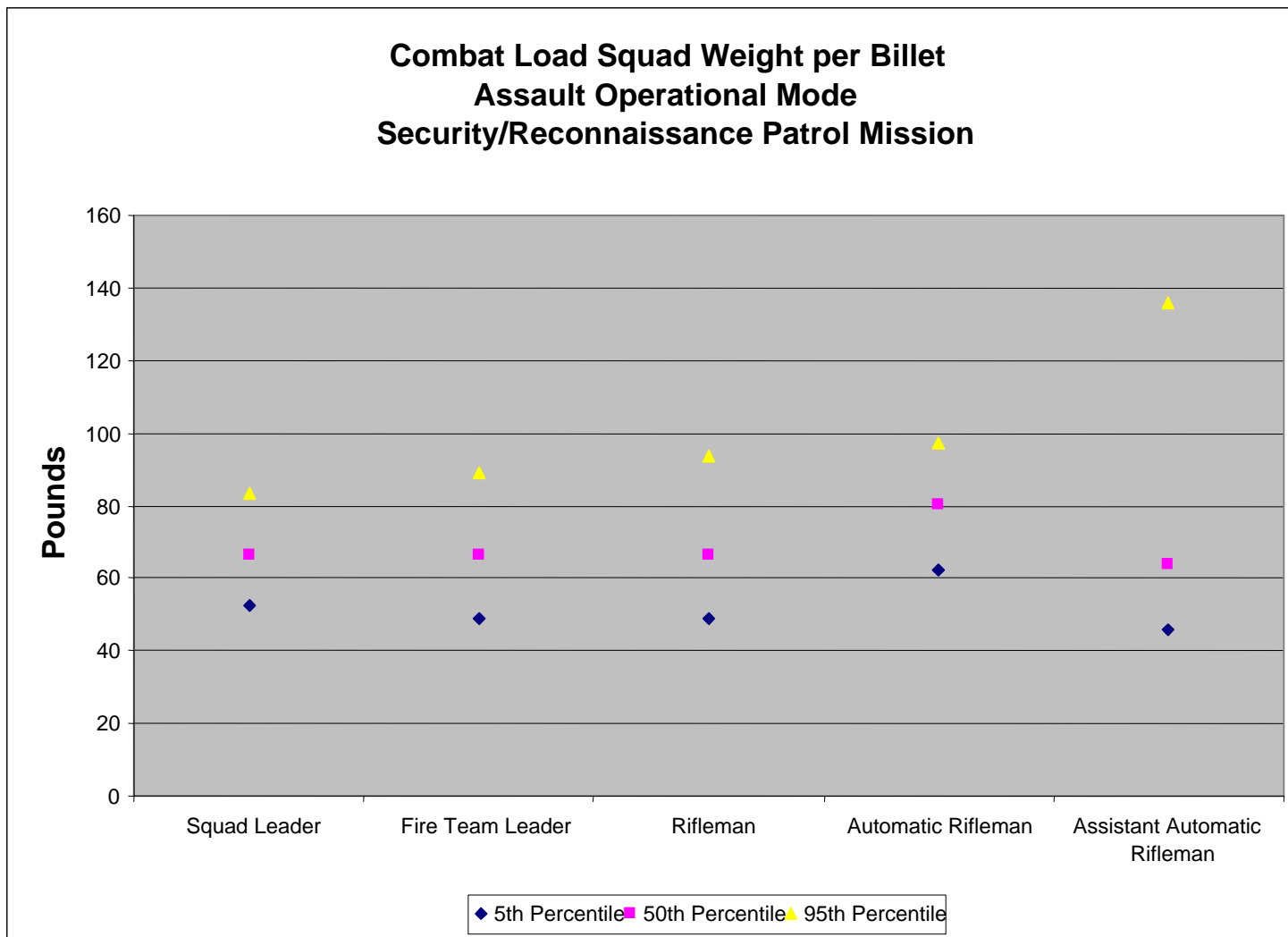
(Assault Operational Mode)





Combat Loads by Billet

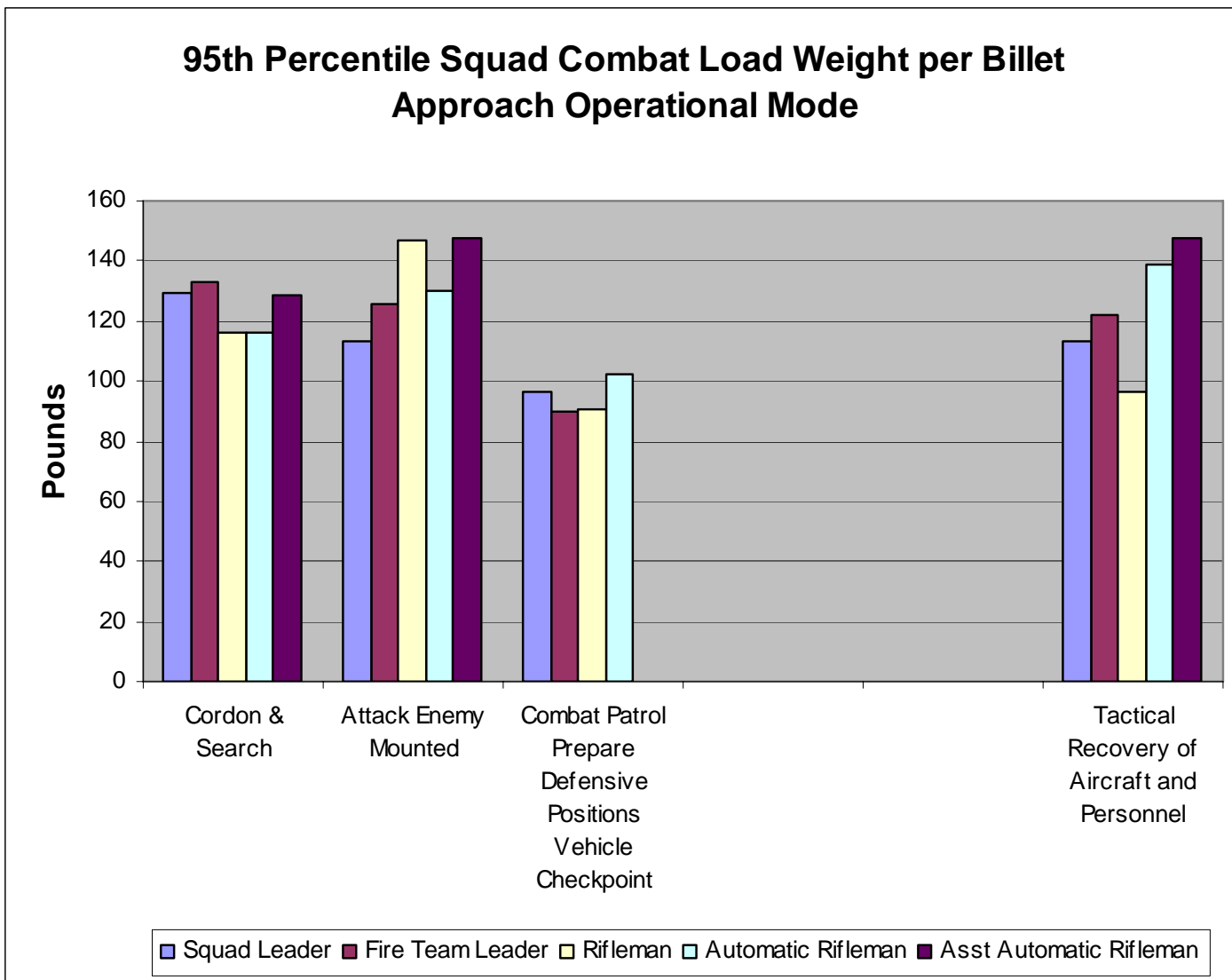
(Approach)





95th Percentile Combat Load by Billet

(Approach Operational Mode)





Tool Estimates Compared to Theater Data



Assault Patrol	Combat Loaded Weight
RIFLEMAN	250.7
RIFLEMAN	247.8
RIFLEMAN	224.5
FTL	258.7
CORPSMAN	252.2
SQD LDR	255.6
RTO	212.5
AR	244.9
GRENADIER	263.2
SQD LDR	194.2
Sum	2404.3
95th Percentile Estimate	2530.8
Conservative Estimate	2587.3

50th Percentile = 2390.2

Approach Patrol 2-Day	Combat Loaded Weight
FTL	274.5
RIFLEMAN	262.2
RIFLEMAN	261.5
AR	248.8
RIFLEMAN	266.5
RIFLEMAN	291.9
FTL	227.4
SQD LDR	298.0
RIFLEMAN	262.9
Sum	2393.70
95th Percentile Estimate	2424.30
Conservative Estimate	2557.20

50th Percentile = 2282.4

If these groups required a transport platform, weight carriage capability built at the 50th percentile could have ended in mission failure.



Outline



- Objective and Assumptions
- Load Weight Demarcations
- Methodology
- Data Collected
- Results
- **Tools**
- **Summary**



Load Weight Tool

Weight Requirements Model (WeRM) ASSAULT

☒ **COMBAT LOADED MARINE**

COMBAT LOADED MARINE (ASSAULT)

PARAMETER INPUTS		OUTPUTS	
Success Rate (5% to 95%)	◀ 95 ▶	Requirement Conservative	
Crew Quantity	1	Combat Loaded Crew Individual Position Requirement	292.8 320.3
Crew Mission Type	CORDON & SEARCH	Combat Loaded Marine Individual Position Requirement	351.8 375.9
Crew Analogy	DRIVER	Combat Loaded Crew Group Requirement	292.8 320.3
Troop Mission Type	ATTACK DISMOUNTED	Combat Loaded Infantry Marine Group Requirement	1288.9 1348.1
		Overall Group Requirement	1581.7 1668.4

Squad & Attachments Inputs

Type	Quantity
SQUAD LEADER	0
FIRE TEAM LEADER	1
RIFLEMAN	1
AUTOMATIC RIFLEMAN	1
ASST AUTOMATIC RIFLEMAN	1
INFANTRY ATTACHMENT	0
NON-INFANTRY ATACHMENT	0
Total	4

Fit Screen

AutoCalc On

Calculate Now

AutoCalc Off

- SQUAD LEADER
- FIRE TEAM LEADER
- RIFLEMAN
- AUTOMATIC RIFLEMAN
- ASST AUTOMATIC RIFLEMAN
- INFANTRY ATTACHMENT
- NON-INFANTRY ATTACHMENT

Developed in the "Squad Weight Study" by Studies and Analysis, MCCDC



Outline



- Objective and Assumptions
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Summary



- Percentile estimation recommended to determine future weight requirements
- Capability exists to determine squad weight for assumptions and missions mentioned previously
- Tool is built for assault and approach operational modes
- Data can be added easily, additional missions would require about two days worth of effort



Questions



Tool

(Inputs)



Percentile of Interest Slider Bar

Check for Combat Loaded Marine or Combat Load ☒

COMBAT LOADED MARINE

PARAMETER INPUTS

Success Rate (5% to 95%)

Crew Quantity

Crew Mission Type

Crew Analogy

Troop Mission Type

Squad & Attachments Inputs

Type	Quantity
SQUAD LEADER	0
FIRE TEAM LEADER	1
RIFLEMAN	1
AUTOMATIC RIFLEMAN	1
ASST AUTOMATIC RIFLEMAN	1
INFANTRY ATTACHMENT	0
NON-INFANTRY ATTACHMENT	0
Total	4

Quantity of each squad billet and any attachments.

Fit Screen

Calculate Now

AutoCalc On

AutoCalc Off

Button to Turn automatic calculation on

Button to calculate if auto calc is off

Button to Turn automatic calculation off

Button to Maximize screen

Support Crew Inputs

Squad & Attachments Inputs

Crew Number

Crew Mission Type

Crew Infantry Analogy

Squad and Attachment Mission Type



Tool (Output)

Indicates whether estimating a combat loaded Marine or Combat load and what operational mode

INFANTRY COMBAT LOAD (ASSAULT)		
OUTPUTS		
	Requirement	Conservative
Crew Combat Load Individual Requirement	0.0	0.0
Troop Individual Combat Load Requirement	91.1	111.9
Crew Combat Load Group Requirement	0.0	0.0
Troop Combat Load Group Requirement	828.3	876.4
Overall Group Requirement	828.3	876.4

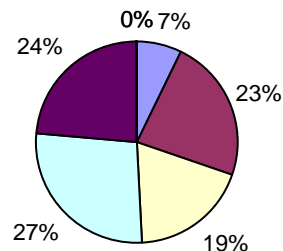
Crew individual estimate

Troop individual estimate

Crew group estimate

Troop group estimate

Total Crew and Troop group estimate



Pie Chart that displays percentage each squad member of total weight is occupying

- SQUAD LEADER
- FIRE TEAM LEADER
- RIFLEMAN
- AUTOMATIC RIFLEMAN
- ASST AUTOMATIC RIFLEMAN
- INFANTRY ATTACHMENT
- NON-INFANTRY ATTACHMENT



Items Carried Tool



Mission ID	Billet	Nude Weight	MOS	Packed Weight (Assault)	Packed Weight (Approach)	Boots Combat With Laces	Boot Size
FMLBRRMDDYYN (see legend in column A at left)	copy and paste from list in column B at left	in pounds	####	weight in pounds with all equipment	weight in pounds with all equipment	QTY	numerical size
040622-5116L-001	ATL		8541/0311			1	8.5
040622-5116L-001	RTO/Observer		8541			2	11.5
040622-5116L-001	Team Leader		8541/0311			1	9W
040622-5116L-001	Spotter/Saw Gunner		0311			2	8.5
040625-5116L-001	Automatic Rifleman	147	0311	236.8		1	10.5
040625-5116L-001	FTL		0311			1	11R
040625-5116L-001	Rifleman	177.4	0311	252.8		1	10R
040625-5116L-001	SAW Gunner		0311			1	9.5
040625-5116L-001	Team Leader	206	0311	280		1	12W
040625-5116L-001	Gunner		0203?	235.4		1	8.5
040625-5116L-001	Automatic Rifleman		0311			1	11
040625-5116L-001	SAW Gunner		0311			1	11.5
040625-5116L-001	Rifleman		0311			2	9.5
040625-5116L-001	FTL		0311	207.4		1	9W
040625-5116L-001	Team Leader		0331			1	11.5
040625-5116L-001	Automatic Rifleman		0311	279.8		2	12W
040625-5116L-001	FTL		0311			1	11
040625-5116L-001	FTL		0311			1	9
040625-5116L-001	Corpsman		8404			1	9W
040625-5116L-001	Rifleman		0311			1	9R
040625-5116L-001	Team Leader		0311	244		1	
040625-5116L-001	Corpsman	222.8	8404			1	11R
040625-5116L-001	FTL		0311	220		1	10
040625-5116L-001	Rifleman		0311			1	9R
040625-5116L-001	Rifleman		0311	203		1	9W
040625-5116L-001	Team Leader		0311			2	10.5
040625-5116L-001	Rifleman		0311			1	9
040625-5116L-001	Team Leader		0311	233		1	12
040625-5116L-001	Automatic Rifleman		0311	311		1	14
040625-5116L-001	Rifleman		0311	264		1	13R
040625-5116L-001	Squad Leader		0311			1	9.5W
040625-5116L-001	Squad Leader		0311			1	